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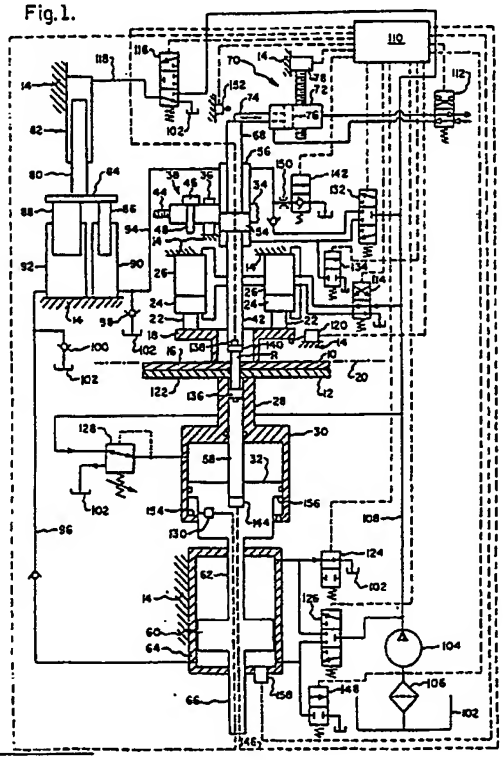
(54) Slug riveting method and apparatus.

(57) A method and apparatus for riveting together two workpieces (10, 12) by simultaneously upsetting both ends of a slug rivet (R) while maintaining the outer surface (16) of one of the workpieces (10) in a substantially constant fixed work plane (20) during riveting. The workpieces are held between two clamps (18, 28), one of the clamps (18) establishing the fixed work plane. After drilling, a slug rivet (R) is placed within the drilled hole, and then a first riveting ram (42) is moved to establish a desired die cavity. A second riveting ram (58) is then moved until it just contacts the rivet. The rams (42, 58) are then simultaneously moved towards each other at equal rates to simultaneously form upset heads on both ends of the rivet.

Fig.1.



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SLUG RIVETING METHOD AND APPARATUS

The present invention relates generally to a riveting method and apparatus.

In the aircraft industry the skin of an aircraft is traditionally riveted to frame members such as stringers or the like. Because of the large number of rivets utilised to produce a single aircraft, and also because of the requirement of virtually indefinite life of the rivets, much attention has been given in the industry to various methods and apparatus for riveting. One riveting method and apparatus which has been utilised by the industry for a number of years is shown in US-A-3,557,442. This patent discloses the utilisation of slug rivets to secure two members together, the workpieces which are to be joined together being initially clamped together. This patent teaches that the upper rivet forming anvil is initially extended to a full down locked position with all of the rivet upsetting force then being applied by upward movement of the lower rivet forming anvil, the ends of the rivet being simultaneously formed. Due to the sequential movement of the rams the surfaces of the workpieces will move relative to a fixed work plane. This is referred to in the industry as a "wink".

As the workpieces are winked or moved during the squeeze cycle of the foregoing process they will have a tendency to oscillate before returning to their original position. This oscillation could delay the neat rivet forming operation or any other subsequent operation. Additionally, if the slug rivet can be formed without winking better control of the position of the slug can be achieved. As there would be no movement of the workpiece even greater uniformity of the bulging of the rivet may be achieved which is desirable for rivet fatigue life cycles. In addition, by not moving the workpieces during the riveting there is a potential for even faster rate times. In addition, the workpieces can be rigidly fixtured thus eliminating the need for temporary fasteners which have subsequently to be replaced.

Therefore, it is an object of the present invention to provide an antiwink slug riveting method and apparatus.

The present invention is defined in the appended claims and achieves its objective by clamping the workpieces together with equal forces on each side of the workpieces, one surface of one of the workpieces lying in a substantially fixed work plane. After the workpieces are clamped together the workpieces are drilled to form aligned apertures therein and a slug rivet is positioned within the aligned apertures. Next one of the riveting ram assemblies is disposed with respect to the slug rivet to form a predetermined die cavity. After this has been accomplished both ends of the slug rivet are contacted by moving the other ram towards that ram which establishes the fixed die cavity. Then, it is only necessary to move the rams together at equal rates and distances to upset the slug rivet. After the rivet has been formed and properly tempered by maintaining the rams together for a predetermined period of time it is only necessary to move the rams away from the upset slug rivet and to then unclamp the workpiece to complete the operation. Optionally the surface of one of the upset heads on the rivet may be milled to lie very close to the outer surface of the workpieces. An apparatus has been developed for carrying out the method described above and it has been found in test work that movement of the surface which lies in the substantially fixed work plane can be held to less than 0.005 of one inch (0.13mm).

It will be seen that the present invention provides a method and apparatus for riveting together two or more workpieces, wherein both ends of a slug rivet are simultaneously upset during riveting, the outer surface of one of the workpieces being maintained in a substantially constant fixed work plane during riveting.

The present invention will now be described in greater detail, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a schematic illustration of the apparatus of this invention, and

Figures 2 to 10 illustrates the sequence of operational steps utilised in the performance of the apparatus and method of this invention.

Reference will be made initially to Figure 1 in which the apparatus of this invention is illustrated. Two workpieces which are to be joined together are indicated at 10 and 12, respectively. While only two workpieces are illustrated in Figure 1, it should be appreciated that more than two workpieces could be joined together by the method and apparatus of this invention. The apparatus includes a principal frame indicated schematically at 14. The frame 14 and the workpieces 10,12 can be moved relative to each other to establish the desired working positions, and when moved relative to each other the frame is so positioned with respect to one outer side 16 of one of the workpieces, namely workpiece 10, that when a first clamp means 18 forming part of the apparatus is fully extended it will contact the one side 16 of the workpiece 10 so that the one side 16 will lie in a substantially fixed work plane indicated by the dot dash line 20. The first clamp means 18 is carried by piston rods 22

which are in turn connected to associated pistons 24 disposed within double-acting first clamp cylinders 26 which are secured to the frame 14.

Mounted below the first clamp means 18 on the opposite side of the workpieces 10, 12 is a second clamp means 28 in a coaxial alignment with the first clamp means 18. The second clamp means 28 is carried by a second clamp cylinder 30 which is in turn supported upon a second clamp piston 32, which is supported in the manner which will be described below.

An indexable subframe 34 is slideably supported by a portion 36 of the main frame 14, the indexable subframe supporting drilling means 38, and milling means 40 not shown in Figure 1 but shown in Figure 9, and a first riveting ram 42. The indexable subframe 34 can be indexed by any conventional mechanism as, for example, a stepper motor and shaft assembly partially illustrated at 44. It can be seen that as the subframe 34 is indexed to its full right-hand position as shown in Figure 1, the drilling means 38 may be placed in an operative position where it is coaxial with the first and second clamp means 18, 28. When the subframe 34 is indexed to an intermediate position the first riveting ram means 42 will be moved from an inoperative position to an operative position wherein it is coaxial with the first and second clamp means 18, 28 and in the meantime the drilling means 38 will be shifted from an operative position to an inoperative position. While the milling means 40 is not shown in Figure 1, it could be positioned on the righthand side of the indexable subframe 34 and further indexing of the subframe would move the milling means from an inoperative position to an operative position where it is also coaxial with the clamp means 18, 28. Each of the drilling means 38 and milling means 40 would include a motor 46, a rotatable arbor shaft 48 to which a suitable tool is secured and means to shift the tool vertically. Thus, the drilling means 38 would include a combined countersink and drill bit 50 (Figure 3) in addition to the motor 46, arbor shaft 48 and vertical shifting means. Similarly, the milling means 40 would include a surface milling cutter 52 (Figure 9).

The first riveting ram means 42 is supported by a first ram piston 54 which is in turn disposed within a double-acting first ram cylinder 56 supported by the indexable subframe 34. When the first riveting ram means 42 is in its operative position, as shown in Figure 1, it is coaxial with a second riveting ram means 58 disposed to the other side of the workpieces 10, 12. The second riveting ram means 58 is movable within the second clamp means 28 and is carried by one end of the second clamp piston 32. The second clamp piston 32 is in turn interconnected with a second ram piston 60 by a piston rod 62, the second ram piston in turn being disposed within a double-acting second ram cylinder 64. The second ram cylinder 64 is in turn rigidly interconnected with the frame 14. In order to provide for stability, the cylinder 64 is double-ended, that is to say not only does piston rod 62 extend out of the upper end as shown in Figure 1, but a lower portion 66 of piston rod 62 extends out of the lower end of cylinder 64. Alternate stabilising methods include dual pistons, where two pistons are used within the same cylinder housing, and external guides which support the cylinder rod in its extended position. Similarly, the first ram cylinder 56 is also double ended, a piston rod 68 extending out of the upper end as viewed in Figure 1. The ram 42 and piston rod 68 are in fact formed of a single rod, with the piston 54 being mounted between the ends of the rod.

Stop means indicated generally at 70 are provided which can be contacted by the upper end of the piston rod 68. The stop means includes a double-acting air cylinder 72 which carries an outwardly extending piston rod 74 which may act as a stop when in its extended position as shown in Figure 1, the piston rod in turn being secured to a piston 76 within the air cylinder 72. The stop means 70 is in turn mounted for adjustable movement towards and away from the piston rod 68 by means of a stepper motor assembly 78 one end of which may be rigidly interconnected with the main frame 14. Alternatively, the stepper motor may be mounted on the indexable subframe 34.

The apparatus of this invention further includes force applying means capable of simultaneously moving the rams 42 and 58 together, which force applying means includes a master piston and cylinder assembly including piston 80 and a single-acting cylinder 82 which is rigidly mounted on the main frame 14. Rigidly supported upon an outwardly-extending portion of the master piston 80 is a cross member 84 to which are secured first and second fluid displacement rams 86, 88 respectively. Each of these rams 86, 88, extends into associated first and second fluid displacement cylinders 90, 92, respectively. These cylinders 90, 92 are in turn rigidly mounted on the main frame 14. It should be noted that the effective square area of the fluid displacement rams 86, 88 are proportional to the effective cross-sectional areas of the first and second ram pistons 54, 60, respectively. The cylinders 90, 92 are in turn interconnected with cylinders 56 and 64, respectively, by suitable fluid lines 94, 96, respectively. Prefill check valve assemblies 98, 100 are interconnected with lines 94, 96, respectively, each prefill valve assembly including a line that extends to the bottom of a reservoir 102. The reservoir 102 is part of the source of fluid under pressure which is utilised to operate the various cylinder assemblies, the source of fluid

pressure including, in addition to the reservoir 102, a pump 104, filter 106 and a main fluid pressure supply line 108. The source of fluid under pressure may be mounted on the frame 14, or may be carried separately and interconnected with the various components by flexible fluid lines.

The apparatus further includes primary control means 110 which are interconnected with various valves and feedback mechanisms which will be described in conjunction with the detailed operation.

The apparatus is properly positioned by moving the apparatus with respect to the workpieces 10, 12 which are to be joined together. In order to ensure proper operation it is necessary that the lower surface of the first clamp means be parallel to the work plane 20 and spaced away from the work plane a distance equal to the travel of the first clamp means when shifted from its initial raised position to its operative lower position (step 1) wherein it just contacts the top surface 16 of the top workpiece 10. Prior to the commencement of operation all fluid control valves are in their blocking positions with the exception of an air cylinder control valve 112 which is in that position which retracts the stop 74, a first clamp cylinder control valve 114 which is in that position which causes the first clamp means or pressure foot bushing 18 to be moved to its raised position, and a master cylinder control valve 116 which causes the fluid line to the master cylinder 82 to be open to reservoir 102. The initial operating position is not shown in the various figures of the drawings. In addition, the apparatus shown in Figure 1 is shown in that position which it occupies at the completion of step 10 set forth below.

After positioning the apparatus with respect to the workpieces 10, 12, the steps set forth then take place. For the convenience of the reader, Table I sets forth the position of each of the control and dump valves at the completion of each of the following steps:-

1. At the commencement of operation the first clamp means 18 is moved all the way down by causing the pistons 24 to bottom out in their respective cylinders 26 by operation of the first clamp cylinder control valve 114 which is switched to a position to extend piston rods 22 by operation of the primary control 110. The apparatus is so designed that the first clamp means 18 will then establish the work plane 20 for the subsequent operations.

2. When the first clamp means 18 contacts a limit switch 120, the primary control means 110 will cause the second clamp means or clamp bushing 28 to be moved upwardly until it contacts the side 122 of the workpiece 12. This operation is commenced by opening the first or upper second ram dump valve 124 to reservoir and simultaneously shifting the second ram cylinder control valve 126 to its "raise piston" position which will cause piston 60, piston 32 and cylinder 30 to commence upward movement. Continued upward movement of the second clamp means 28 will continue until workpieces 10 and 12 become tightly sandwiched between the first and second clamp means 18 and 28. However, the second clamp piston 32 continues to be moved upwardly after clamping is achieved, and fluid trapped within the second clamp the cylinder 30 is forced out through a pressure control valve 128 which holds the fluid within the cylinder 30 at a constant pressure. This maintains a constant force between the first and second clamp means 18, 28.

3. Step 2 will be completed when the clamp signal device 130 is actuated which will send a signal to the primary control 110 which will in turn command valves 124 and 126 to shift to their blocking positions, thereby locking piston 60 in place within cylinder 64. The clamp signal device 130 is a proximity switch sensor which senses differential movement between the second clamp cylinder 30 and the second clamp piston 32. The sensor 130 is adjustable during initial machine set up to account for physical differences between machines. The completion of the clamping step is illustrated in Figure 2.

4. Aligned apertures are then drilled through the workpieces 10 and 12. At the same time a countersink is produced in workpiece 10 to a preset depth. The drill 50 for the above is carried by the subframe 34 which also supports the first ram cylinder 56. Thus, the subframe 34 is suitably indexed to its proper location for the drilling operation. A slug rivet R is inserted into the cavity below the first riveting ram 42 while the drilling operation takes place in accordance with the method and apparatus disclosed in US-A-4,819,856, the subject matter of which is incorporated herein by reference thereto. The drilling step is illustrated in Figure 3. At completion of the drilling step the drill bit 50 will be retracted so that it is above the top of the first clamp means 18.

5. The subframe 34 which carries the drilling apparatus is then indexed to another position to place the first riveting ram 42 in an operative position wherein it is aligned with the apertures in workpieces 10, 12. The first ram cylinder control valve 132 and the first or lower first ram cylinder dump valve 134 will then be operated by the primary control 110, valve 132 being shifted to a position to cause the first riveting ram 42 to be moved downwardly, and valve 134 being opened to permit discharge of fluid to reservoir 102. This operation will force the slug rivet R into the aligned apertures which were drilled in step 4, the tail of

the rivet being freely contained by the cavity between the anvil 136 on the end of the second rivet ram means 58 and the adjacent structures.

6. A ram proximity switch 138 will sense when the first riveting ram 42 has moved downwardly to a fully lowered or bottomed out position where the lower end of the anvil 140 carried by the lower end of the ram 42 is disposed a fixed distance above the work line, for example 0.015 inches (0.38mm). The primary control will then cause valves 132 and 134 to shift to their blocking positions. The completion of this step is illustrated in Figure 4. The anvils 136 and 140 (which may include separable die buttons) are so selected that there will be equal metal displacement at each end of the rivet during the upsetting operation set forth in step 12 below. In other words, the anvils 136 and 140 must be properly paired for equal metal displacement.

7. The stop 74 is now extended by causing the valve 112 to shift to its other position. In order properly to establish the upper cavity, which is necessary to ensure that the rivet R is properly formed, the stop must be in the proper vertical position. The vertical position of the stop is adjusted via stepper motor and output drive 78 by the primary control 110 to programmed dimensions selectable from the operator's station, the stop cylinder 72 being interconnected with the stepper motor output drive. The operator does this initially to establish the required upper cavity, the particular location of the stop 74 being determined by the thickness of the workpieces and the length and diameter of the slug rivet R.

8. Next the valve 132 will be operated to raise the ram 42 and piston rod 68 to the stop 74 to set the upper cavity, a second or upper first ram cylinder dump valve 142 also being shifted to its open position to permit discharge of fluid from the upper end of the cylinder 56 during this step. The completion of this step is illustrated in Figure 5. When the upper end of the piston rod 68 contacts the stop 74, the upper cavity will be properly set.

9. After the rod 68 contacts the stop 74 the second rivet ram 58 is raised by operation of valve 126 and valve 124 which cause the rivet R to be lifted towards the upper anvil, valve 126 being shifted to its position which causes the piston 60 to be moved towards the workpieces 10, 12, and valve 124 being shifted to that position which permits fluid from the upper end of the second ram cylinder (as viewed in Figure 1) to be dumped to reservoir 102. 10. The foregoing step will be completed when a load cell 144, which is mounted between the second rivet ram 58 and the second clamp piston 32, senses contact of the rivet R with the anvil 140. When contact is sensed, a signal will be transmitted through a feedback line 146 to the primary control 110 which will then cause valves 124, 126, 132 and 142 to be shifted to their blocking positions. The completion of this step is illustrated in Figure 6, as well as in Figure 1.

11. The primary control means 110 will now cause the master cylinder and piston assembly 80, 82 to be operated to form the rivet R. It should be noted that at this time the upper chamber of the cylinder 64 is being vented to reservoir through dump valve 124. Initially the dump valve 134 will be shifted to its open position to permit the lower chamber of cylinder 56 to be vented to reservoir.

12. After dump valve 134 has been opened, the master cylinder control valve 116 will be shifted to a position wherein fluid is directed into the master cylinder 82 through line 118. As the master piston 80 is extended, the ganged displacement rams 86, 88 will be forced into the displacement cylinders 90 and 92, respectively, which will in turn cause fluid to be discharged from the cylinders 90 and 92. The cylinders 90 and 92 are so sized that the volumes of oil which are displaced from the cylinders will cause equal and simultaneous movement of pistons 60 and 54 towards each other to cause anvils 136 and 140 to move towards each other at equal rates simultaneously to form upset heads on both ends of the rivet R while the surface 16 of workpiece 10 continues to be maintained in the work plane 20. Test results indicate that movement of the surface 16 with respect to workline 20 is held to less than 0.005 inches (0.13mm) during this step. At the same time that the anvils are upsetting both ends of the slug rivet R the valve 112 will be shifted to its other position to cause the stop 74 to be retracted. The completion of this step, which occurs when the riveting ram 42 has moved down to its bottomed out position, is sensed by the lower ram load cell 144 reaching a predetermined force setting which, in turn, triggers an adjustable dwell time within the primary control means 110. The predetermined force setting is just slightly less than actual peak force and is set to indicate the force setting desired momentarily before top ram 42 bottoms out. In the event that the predetermined force setting is not achieved, the operator must override the controls. The bottoming out of ram 42 will stop further movement of the slave cylinders.

13. When the dwell time is completed, the valve 116 will then be shifted to a decompression or blocking position and the operation of a decompression timer will be initiated.

14. When the decompression timer times out, the valve 116 will be shifted to a squeeze retract or open to reservoir position and will remain there until the next machine cycle. Valves 124 and

136 will also be shifted to their closed positions. The completion of this step is illustrated in Figure 7.

15. The second rivet ram means 58 is now commanded to retract to a backaway position by momentarily opening the second or lower second ram cylinder dump valve 148 to reservoir and shifting valve 126 to that position which will cause piston 60 to move away from the workpieces 10, 12.

16. At the completion of step 15, the valves 126 and 148 are shifted back to their blocking positions.

17. Valve 132 is now commanded by the primary control 110 to be shifted to a position which causes the first riveting ram 42 to be moved away from the workpieces and valve 142 is also shifted to its open position. Because of the restriction 150 in the line from the first ram cylinder 56 to dump valve 142 most of the oil being displaced from the cylinder 56 is forced through the line 94 leading to displacement cylinder 90. The oil flowing into the cylinder 90 forces the ram 86 out of the cylinder which in turn causes the master cylinder piston 80 of the master cylinder 82 to retract to its home position. During this action, the ram 88 in cylinder 92 is being pulled outwardly of cylinder 92 and causes oil to be sucked into the cylinder from the tank through the prefill valve 100. Oil displaced from master cylinder 82 will flow to reservoir 102 through valve 116.

18. When the first riveting ram 42 is fully retracted, which is sensed by limit switch 152 being contacted by rod 68, the dump valve 142 will be shifted back to its closed position, and valve 132 will be shifted to its blocking position. The completion of this step is illustrated in Figure 8.

19. Now, optionally, the subframe 34 which carries the cylinder 56 will be indexed to a further position and a milling cutter 40 will be brought into contact with upper surface of the deformed slug and will shave it to within 0.002 of an inch (0.05mm) of the surface 16. The milling cutter 40 will then retract after the completion of this operation and the indexable subframe 34 will return to its drill position. The shaving step is illustrated in Figure 9.

20. Dump valve 148 will now be commanded to open by the primary control means 110 and valve 126 will also be commanded to shift to cause oil to be delivered to the top of the cylinder 64. As fluid flows into the top of the cylinder 64, the piston 60 will be moved downwardly carrying with it the piston 32, the cylinder 30 and the second clamp means 28. As there is substantially constant pressure on the cylinder 30 at all times, due to its connection with the pressure control valve 128, it will extend during this time until its inwardly-extending flange 154 contacts the stop surface 156 on piston 32. The second clamp means 28 will now disengage from the lower surface 122 of the workpiece 12 and travel down with the second rivet ram means 58 until its desired position is sensed by an adjustable proximity switch 158.

21. When the desired lower position is achieved, the primary control 110 will now command valves 126 and 148 to return to their blocking positions. Upon completion of the head transfer back to the drill position, a command will be issued to the shift valve 114 to its other position to cause the first clamp means 18 to raise from the workpiece 10 The completion of this step is illustrated in Figure 10. As the workpiece 10, 12 is now unclamped, the entire apparatus may be moved relative to the workpieces 10, 12 to the next rivet position.

Claims

1. A method of riveting together two or more side-by-side workpieces (10,12), the workpieces being provided with aligned apertures in which a slug rivet (R) has been received, one side (16) of one workpiece (10) establishing a substantially fixed work plane (20); characterised in that the method comprises the following steps:-

providing first and second riveting ram means (42,58) aligned with the slug rivet (R), the first riveting ram means (42) being disposed adjacent said one side (16) of said one workpiece (10), and the second riveting ram (58) being disposed away from the outer side (122) of another workpiece (12);

moving the first riveting ram means (42) with respect to the work plane (20) to establish a first desired die cavity;

moving the second riveting ram means (58) towards the first riveting ram means (42) until both ends of the slug rivet (R) are just in contact with both riveting ram means; and

simultaneously moving the first and second riveting ram means (42,58) towards each other at equal rates so as simultaneously to form upset heads on both ends of the slug rivet (R) while said one side (16) of the one workpiece (10) continues to be disposed in the work plane (20).

2. A method according to claim 1, characterised in that the the simultaneous moving of the first and second riveting ram means (42,58) is accomplished by the application of fluid pressure, the pressure being applied for a dwell time after a pre-determined force is sensed when the heads on both ends of the rivet are substantially fully upset.

3. A method according to claim 2, characterised in that the source of fluid pressure to the first and second riveting ram means (42,58) is blocked during a decompression period of time.

4. A method according to claim 3, characterised in that the fluid pressure is dumped at the completion of the preceding step, and in that the first and second riveting ram means (42,58) are moved away from each other after the fluid pressure is dumped.

5. A method according to any of the preceding claims, characterised in that the first and second riveting ram means (42,58) are moved away from each other after the upset heads on both ends of the rivet (R) are fully formed, and further characterised by the step of milling the upset head on one end of the rivet (R) which lies adjacent said one side (16) of said one workpiece (10) so that after milling, the milled surface of the rivet lies substantially flush with said one side of said one workpiece.

6. A method of riveting together two or more side-by-side workpieces, characterised in that it comprises the following steps:

providing first and second clamp means (18,28) and first and second riveting ram means (42,58) aligned with each other, the first clamp means (18) and first riveting ram means (42) being disposed to one side of one of the workpieces (10) and the second clamp means (28) and second riveting ram means (58) being disposed away from the outer side of another workpiece (12);

moving the first clamp means (18) into contact with said one side (16) of said one workpiece (10) to establish a fixed work plane (20);

moving the second clamp means (28) towards the first clamp means (18) to clamp the workpieces (10,11) between the first and second clamp means with a constant force, with said one side (16) of said one workpiece (10) being maintained in said fixed work plane (20);

positioning a rivet (R) within aligned apertures in the workpieces (10,11), the aligned apertures being in alignment with the first and second riveting ram means (42, 58);

contacting respective ends of the slug rivet (R) with the first and second riveting ram means (42,58);

simultaneously moving the first and second riveting ram means (42, 58) towards each other to apply equal rates so as simultaneously to form upset heads on both ends of the rivet (R) while the first and second clamp means (18,28) maintain said one side (16) of said one workpiece (10) in the fixed work plane (20);

moving the first and second riveting ram means (42, 58) away from each other after the upset heads on both ends of the rivet have been formed; and

subsequently moving the first and second clamp means (18,28) away from each other to unclamp the workpieces (10,11).

7. A method according to claim 6, and further characterised by the step of moving the first riveting ram means (42) with respect to the fixed work plane to establish a first desired die cavity, and in that both ends of the rivet (R) are contacted by the first and second riveting ram means (42,58) by moving the second riveting ram means towards the first riveting ram means after the first desired die cavity has been established until both ends of the slug rivet (R) are just in contact with both riveting ram means.

8. A method according to any of the preceding claims, wherein drilling means (38) are provided, and further characterised by the step of drilling aligned apertures through the workpieces (10,11) after the workpieces have been clamped together and prior to the step of positioning the rivet within the aperture.

9. A method according to any of the preceding claims, wherein milling means are provided, and further characterised by the step of milling the upset head on that end of the rivet (R) which lies adjacent said one side (16) of said one workpiece (10).

10. A method according to claim 8 or claim 9 when appended to claim 8, wherein an indexable sub-frame (34) is provided on which are mounted the first clamp means (18) and the drilling means (38), characterised in that it comprises the further steps of:

moving the Indexable subframe (54) to a first position to position the drilling means (38) in an operative position and the first riveting ram means (42) in an inoperative position; and

moving the indexable subframe, after the drilling step, to a second position in which the drilling means (38) is in an inoperative position and the first riveting ram means (42) is in an operative position in alignment with the aligned apertures and with the second riveting ram means (58);

11. Apparatus for riveting together two or more side-by-side workpieces (10,12), the workpieces being provided with aligned apertures in which a slug rivet (R) has been received, one side (16) of one workpiece (10) establishing a substantially fixed work plane (20); characterised in that the apparatus comprises;

first and second riveting ram means (42,58) aligned with the rivet (R), the first riveting ram means (42) being disposed adjacent said one side (16) of said one workpiece (10), and the second riveting ram means (58) being disposed away from the outer side (122) of another workpiece (12);

first means (54,56) operable to move the first riveting ram means (42) with respect to the work plane

(20) to establish a first desired die cavity;
second means (60,62,64) operable to move the second riveting ram means (58) towards the first riveting ram means (42) until respective ends of the rivet (R) are just in contact with the first and second riveting ram means; and
force-applying means (80,82) capable of simultaneously moving the first and second riveting ram means (42, 58) towards each other at equal rates so as simultaneously to form upset heads on both ends of the rivet (R) while said one side (16) of said one workpiece (10) continues to be disposed in the work plane (20).

12. Apparatus according to claim 11, characterised in that said first and second means are in the form of first and second ram pistons (54;60) mounted within first and second ram cylinders (56; 64), respectively, and in that the force-applying means includes means (82) for introducing fluid into each ram cylinder (56;64) to displace the first and second ram pistons towards each other, the volume of the fluid being introduced into each ram cylinder being proportional to the effective area of each ram piston, whereby the first and second ram pistons will be moved towards each other at the same rate.

13. Apparatus according to claim 11 or 12, characterised in that the force-applying means further includes first and second commonly mounted fluid displacement rams (86,88) which are movable into associated fixed first and second displacement cylinders (90, .92) from which fluid is displaced under pressure, the effective cross-sectional area of the first and second fluid displacement rams being proportional to the effective cross-sectional areas of the first and second ram pistons (54;60), respectively.

14. Apparatus according to claim 13, characterised in that the force-applying means includes a further master piston and cylinder assembly (80,82) which is coupled to the two commonly mounted fluid displacement rams (86,88).

15. Apparatus according to any of claims 11 to 14, characterised in that it further comprises stop means operable to limit movement of the first riveting ram means (42), the first riveting ram means being moved against the stop means by the means (54,56) for moving the first riveting ram means, whereby the first desired die cavity is established.

16. Apparatus according to any of claims 11 to 15, characterised in that one of the first and second riveting ram means (42,58) is so designed that there will be equal metal displacement at each end of the rivet when both ends of the rivet are simultaneously upset.

17. Apparatus according to any of claims 11 to 16, characterised by the provision of means to move the first and second riveting ram means (42,58) away from each other after the upset heads on both ends of the rivet (R) have been formed.

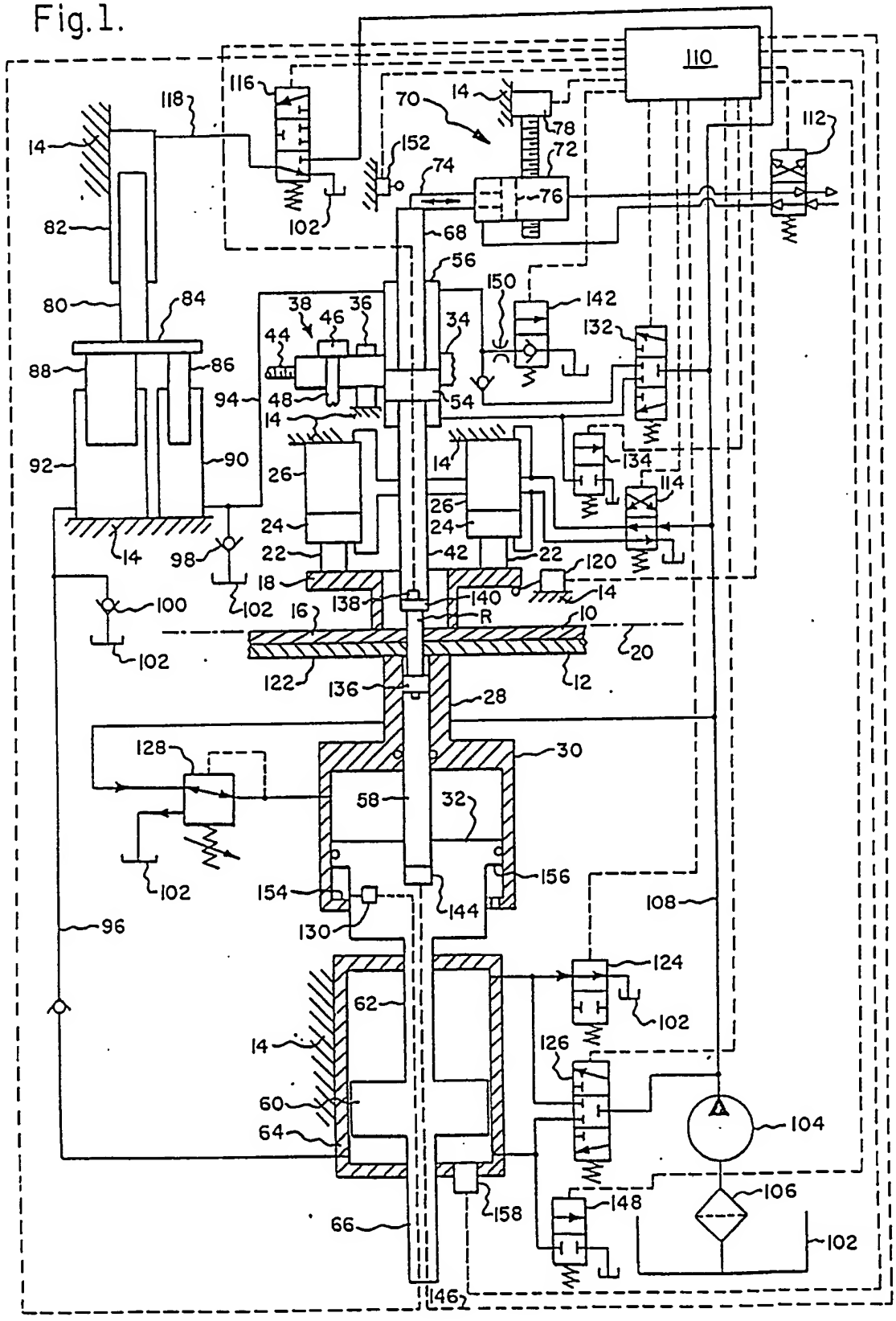
18. Apparatus according to any of claims 11 to 17, characterised in that it further comprises:
first and second clamp means (18,28), one clamp means (18) being disposed to one side (16) of the workpieces (10,12) and the second clamp means (28) being disposed to the outer side (122) of another workpiece (12);
means (22,24,26) operable to move the first clamp means (18) into contact with said one side (16) of said one workpiece (10) to establish a fixed work plane (20);
means (30,32) operable to move the second clamp means (28) towards the first clamp means (18) to clamp the workpieces (10,12) between the first and second clamp means with a constant force, with said one side (16) of said one workpiece (10) being maintained in said fixed work plane (20);
rivet positioning means capable of positioning a slug rivet (R) within aligned apertures in the workpieces, the aligned apertures being in alignment with the first and second riveting ram means; and
means operable subsequently to move the first and second clamp means (18,28) away from each other to unclamp the workpieces.

19. Apparatus according to any of claims 11 to 18, characterised in that further includes an indexable (34) subframe mounted to said one side (16) of the workpieces (10;12), the first riveting ram means (42) being mounted on the subframe for movement between operative and inoperative positions, and drilling means (38) mounted on the subframe for movement between operative and inoperative positions, the drilling means being operable to drill aligned apertures through the workpieces when the drilling means is in its operative position and after the workpieces have been clamped together.

20. Apparatus according to any of claims 11 to 19, characterised in that it further comprises milling means (40) operable to mill the upset head on that end of the rivet (R) which lies adjacent said one side (16) of said one workpiece (10).

21. Apparatus according to claim 20 when appended to claim 19, characterised in that the milling means (40) is carried by the indexable subframe (34) for movement between operative and inoperative positions.

Fig.1.



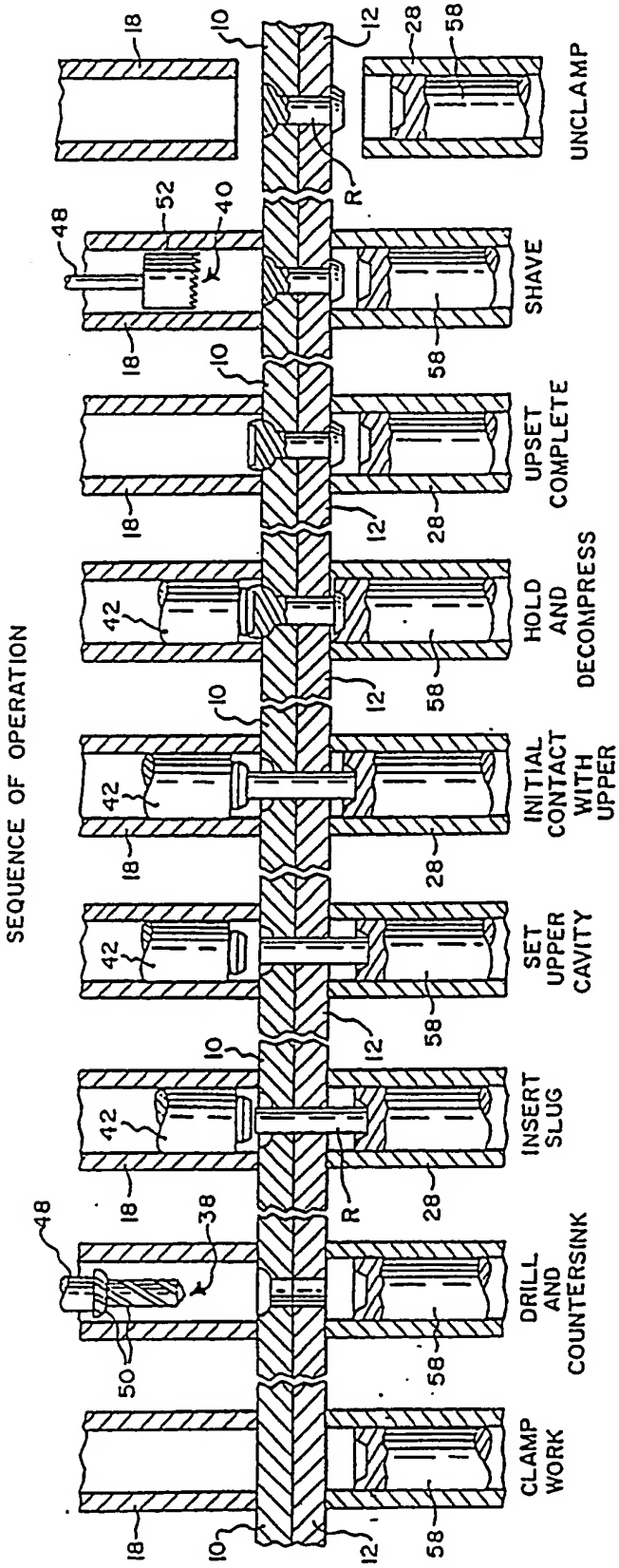


Fig.2. Fig.3. Fig.4. Fig.5. Fig.6. Fig.7. Fig.8. Fig.9. Fig.10.

TABLE I

VALVE → / STEP ↓	112	114	116	124	126	132	134	142	148
1	A	A	A	A	B	B	A	A	A
2	A	A	A	B	A	B	A	A	A
3	A	A	A	A	B	B	A	A	A
4	A	A	A	A	B	B	A	A	A
5	A	A	A	A	B	C	B	A	A
6	A	A	A	A	B	B	A	A	A
7	B	A	A	A	B	B	A	A	A
8	B	A	A	A	B	A	A	B	A
9	B	A	A	B	A	A	A	B	A
10	B	A	A	B	B	B	A	A	A
11	B	A	A	B	B	B	B	A	A
12	A	A	C	B	B	B	B	A	A
13	A	A	B	B	B	B	B	A	A
14	A	A	A	A	B	B	A	A	A
15	A	A	A	A	C	B	A	A	B
16	A	A	A	A	B	B	A	A	A
17	A	A	A	A	B	A	A	B	A
18	A	A	A	A	B	B	A	A	A
19	A	A	A	A	B	B	A	A	A
20	A	A	A	A	C	B	A	A	B
21	A	B	A	A	B	B	A	A	A

VALVES 124, 134 142 & 148	POSITION	A – FLOW BLOCKED
	POSITION	B – FLOW THROUGH TO RESERVOIR
VALVE 112	POSITION	A – RETRACT STOP
	POSITION	B – EXTEND STOP
VALVE 114	POSITION	A – EXTEND CYLINDER
	POSITION	B – RETRACT CYLINDER
VALVE 126	POSITION	A – RAISE PISTON
	POSITION	B – FLOW THROUGH VALVE BLOCKED
	POSITION	C – LOWER PISTON
VALVE 132	POSITION	A – RAISE RAM
	POSITION	B – FLOW THROUGH VALVE BLOCKED
	POSITION	C – LOWER RAM
VALVE 116	POSITION	A – DRAIN TO RESERVOIR
	POSITION	B – FLOW THROUGH VALVE BLOCKED
	POSITION	C – EXTEND MASTER CYLINDER